BARTH

Mortar making qualities of Illinois sands

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MORTAR MAKING QUALITIES OF ILLINOIS SANDS

BY

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This is to certify that the thesis of GEORGE ANDREW CHRISTIAN BARTH entitled Mortar Making Qualities of Illinois Sands is approved by me as meeting this part of the requirements for the degree of Bachelor of Science in Civil Engineering.

C. C. Wiley
Instructor in Charge.

Approved:

Ira O. Baker.
Professor of Civil Engineering.

Contents

Mortar Making Qualities of Illinois Sands.

Concrete has been in use as a building material from very remote times, but it is only since the beginning of the manufacture of Portland cement that it has been used to any great extent. The development of the Portland cement industry has so stimulated the use of concrete that today it occupies a preeminent position in engineering work. From the very beginning of the Portland cement era the users of cement have constantly demanded an improvement in the quality of cement in order to obtain the best concrete, and the manufacturers have been constantly improving the quality of the product until at the present time they have apparently reached the limit which can be economically attained. Recently, however, the consumers have begun to realize that the other ingredients, which form by far the greater bulk of the concrete,

play as important a part in its quality as does the cement and that too little care has been exercised in the selection of these materials. In most cases contractors have been permitted to use such sand and gravel or broken stone as could be most conveniently obtained at the least cost. In contracts for the erection of concrete structures the specifications usually are very rigid in regard to the cement to be used but generally contain very little concerning the sand or gravel, to be used, leaving this almost entirely to the judgement of the engineer in charge or more frequently to the contractor. This has been very unfrortunate in that often a comparatively poor sand has been used when one of much better quality is easily obtainable and it would doubtless be more economical to use the better sand and less cement than to increase the proportion of cement in order to attain the desired

strength with the poor sand.

There has been considerable experimental work done in recent years in order to determine the effect of the sand on the quality of the mortar. A series of experiments have been performed at the University of Illinois, to determine the value for mortar making of representative sands obtained from different parts of the state of Illinois. These experiments have been carried on for the most part by members of the senior civil engineering classes, in connection with their bachelor's theses. This work of investigation was started in 1907, Mr. J. W. McManis '07, Mr. E. B. Adams '08, and Mr. F. T. Heyle '09, in turn having contributed to this work.

The series of experiments herein recorded, were made by the writer as a continuation of the above tests and were made to determine the relative value for making mortar, of different sands in common use in some of the more

important cities of Illinois

The sands used in this investigation were received in response to letters of request which were sent to the city engineers of a number of the larger cities of Illinois. Sixteen samples were thus obtained, eight of which were assigned to the writer, and eight to Mr. W. Keostner, who is preparing a similar thesis. The writer is indebted to the city engineers of the following cities for the sands used in these tests; namely, Paris, Taylorville, Cairo, Mt. Carmel, Jacksonville, and Peoria.

Description of Tests.

On receiving the samples at the laboratory they were given a sample number, thoroughly dried, and then stored to keep them in a dry condition. Reasonable care was exercised to perform all of the tests under similar conditions for which reason a number of prelimenary

tests were made by the writer in each case before undertaking the final tests.

The following tests were made, namely; Tensile Strength, Fineness, Specific Gravity, Percentage of Voids, and Cleanness.

The tensile test consisted in making eighteen briquettes of each sand. These briquettes were tested at three different ages, one third at seven days, one third at twenty eight days, and the remaining one third at ninety days. In order to have some basis of comparison, the writer made a number of briquettes of the standard Ottawa sand and of neat cement. These were also tested at the thee different ages.

Among the sands collected there were a few that contained considerable suspended matter. In order to determine what effect this had on the tensile strength, the writer chose three of the dirtiest sands, made six

briquettes of each in their original condition, and six of each sample after the suspended matter had been removed by washing. These were all tested at the age of twenty eight days.

The cement used in the tensile tests was taken from one bag of American Portland cement (Chicago A-A). To insure absolute uniformity, before using any of it, the cement was emptied into a number of pans and returned to the bag by taking small quantities from each pan in succession. This precaution being taken to eliminate any variation in tensile strength due to the quality of the cement. The cement fulfilled the standard specifications for Portland cement and required 21.5 o/o of water for normal plasticity.

A proportion of one part cement to three parts of sand, by weight, was used in making all of the briquettes. The percentage of water

was also kept constant, using nine and one tenth (9.1 o/o) percent throughout the work, corresponding to ~~the~~ 21.5 o/o required by the neat cement.

Two hundred and fifty grams of cement were added to seven hundred and fifty grams of sand, this being sufficient for six briquettes, and then thoroughly mixed dry after which ninety one grames (9.1 o/o) of water were added to the mixture. As soon as the water was absorbed the mixture was thoroughly troweled, each batch being cut thru six times.

After the mortar had been mixed to the proper consistency it was put into the molds. The molds were filled with three increments, each mold being partly filled, then firmly pressed with the fingers, this process being repeated until the molds were completely filled and, the mortar then smoothed off with the trowel. The molds used were of the standard bronze gang type.

The molds containing the briquettes were covered with a wet cloth and a tin pan placed over all. After twenty four hours the briquettes were removed from the molds and stored in running water, maintained at about 70° F., until they were tested.

The briquettes were tested at the ages of seven, twenty-eight, and ninety days. A Riehle direct reading automatic shot machine was used in all the testing, the load being applied at a uniform rate of six hundred pounds per minute. The results of these tests are recorded in tables 1, 2, 3 and 4, pages 25 to 29.

Fineness

The fineness test was made by sifting the sands on a mechanical device known as the Per Se Testing Sieve Agitator. The machine is driven by a motor at one hundred revolutions per minute and given a combined vertical and circular motion. There

are two vertical drops during each revolution which combined with the circular motion is very similar to hand shaking. The set of seives used consistedof twelve circular seives about eight inches in diameter and two inches deep, so constructed as to fit into one another, the seive with the largest mesh being placed on top, the finest at the bottom, with the intermediate ones coming in between in their regular order. The different size seives are distinguished by numbers which denote the number of meshes per linear inch.

All of the sands, before using, were passed over a one quarter inch seive, only the part passing this seive being used in the tests. The method of making the seive analysis consisted in weighing out one thousand grams of the sand to be tested and placing the same on the top seive. The nest of seives were then clamped in the machine and

agitated for forty minutes. At the end of this time the sand remaining on each seive was carefully weighed. From these results the percent retained on each seive and also the percent passing were calculated.

Specific Gravity.

The apparatus used in determining the specific gravity was a Schuman Specific Gravity Flask which consists of a simple flask with a short neck into which the end of a long glass tube, graduated into tenths of a cubic centimeter, is fitted very closely making a water tight joint.

The process consisted in pouring water into the flask until it began to rise in the tube, and then a zero reading was taken. Fifty grams of the sand to be tested were then poured into the tube and a second reading taken.

The difference of the two readings gave the volume of the water displaced by the fifty grams of sand. The specific gravity of the material was then calculated by dividing the volume of the water displaced by the weight of the sand used. The results of this test are recorded in table number six.

It was necessary to exercise considerable care in this operation. The inside of the glass tube above the level of the water had to be kept dry in order that the sand would not adhere to the sides on being poured into the flask. It was also necessary to remove the air bubbles from the sides of the flask before each reading.

Percentage of voids.

The method used in determining the percentage of voids was as follows: measured out five hundred cubic centimeters of sand, weighed

the same, and then calculated the percentage of voids by dividing the weight of the five hundred cubic centimeters by the specific gravity of the sand, subtracting the quotient from five hundred, and dividing the difference by five hundred. The sand was measured in a graduated cylinder. In order to eliminate any error due to the degree of compacting of the material in the cylinder it was filled by increments and the cylinder jarred upon a cushioned table a fixed number of times after the addition of each quantity of sand. The sand was added in quantities of about twenty five grams and compacted by jarring the cylinder upon the cushioned table thirteen times after the addition of each increment. The results of this test are recorded in table 6 page 30.

Clearness

The method used in determining the percentage of suspended matter consisted in weighing out a sample of the sand to be tested, then, in turn, washing, drying and reweighing the same. The process used in washing was to place one thousand grams of sand in a large glass vessel filled with water and then with a glass rod or the hand wash the sand until the water became saturated with clay. The contents were allowed to stand for a short time in order that the small particles of sand might settle. The water was then removed by a siphon, care being taken not to bring the tube too near the surface of the sand and thereby allowing any of the sand particles to escape. This process was repeated until the sand was thoroughly cleaned. The sand was then removed from the jar to a tin pan and placed in the dryer. After being thoroughly

dried the sand was reweighed and the difference between the initial and final weight of the sample was equal to the amount of material removed. From this result the percentage of suspended matter was computed. The results of this test are recorded in table 5, page 29.

Description of Sands.

Sample No. 1.

This is a bank sand occurring in small deposits near Paris, Ill. It is very fine, fairly clean, containing 1.2 % of suspended matter. Sp. Gr. 2.65 Percent Voids 35.8 % Wt. per cu. ft. 106.4 lbs.

Sample No. 1

Sample No. 2

This is also a bank sand. It occurs in large deposits near Taylorville, Ill. This is an exceptionally fine sand with no pebbles in it. It is the

Sample No. 2

dirtiest of the sands tested, containing 3.94 % of suspended matter. The grains are fairly rounded and are of a uniform light buff color. Sp. Gr. 2.64 Percent voids 39.5 % Wt. per cu. ft. 100.0 lbs.

Sample No. 3

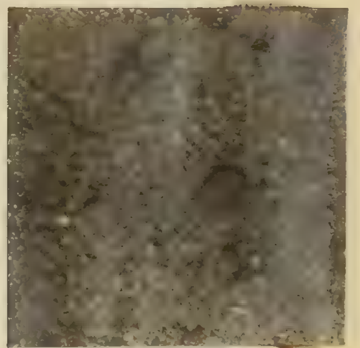
This sand was obtained from the Halliday Sand Co. Cairo, Ill. It is taken from deposits in the bed of the Ohio river, the supply being practically unlimited.


Sample No. 3

It is a very clean, sharp sand, of a grayish brown color. Sp. Gr. 2.64 Percent voids 35.0 % Wt. per cu. ft. 107.3 lbs.

Sample No. 4

This sample of sand was taken from large deposits in the bed of the Mississippi river near Hannibal Mo.. It was sent from Jacksonville, Ill., where it is used very largely in concrete construction.


Sample No. 4

This is a very sharp, well graded sand, being the best graded of the eight samples tested. It is a very clean sand of a dark gray color. Sp. Gr. 2.69 Percent voids 31.9 % Wt. per cu. ft. 114.5 lbs.

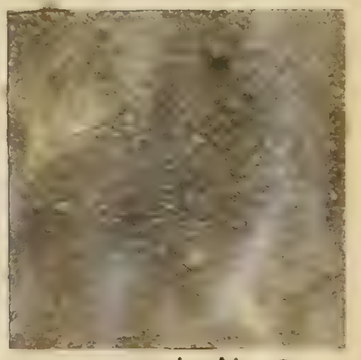
Sample No. 5.

This sample was obtained from Mt. Carmel, Ill., being taken from the bed of the Wabash river. This sand is almost as fine as the Taylorville sand. It contains considerable suspended matter, being the dirtiest of the river sands tested. It ranges in color from light to dark brown. Sp. Gr. 2.61 Percent voids 38.1 % Wt. per cu. ft. 101.0 lbs.

Sample No. 5

Sample No. 6.

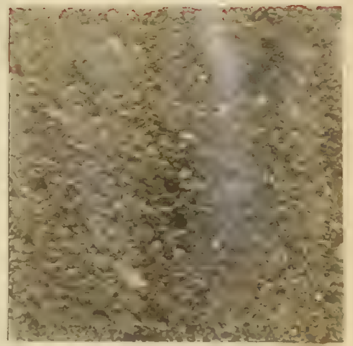
This sample was obtained from the Crescent Gravel Pit at Peoria. It is a fairly clean sand, containing more large particles than any of the other sands tested. Sp. Gr. 2.66 Percent voids 33.8 %



Sample No. 6

Wt. per cu. ft. 110.0 lbs.

Sample No. 7



Sample No. 7

This sample was taken from a sewer trench in Peoria, near the center of the city. It contains mostly smooth rounded particles. One objection to this sand is the foreign matter, such as twigs, leaves, and cinders that it contains. Sp. Gr. 2.64 Percent voids 35.0 o/o Wt. per cu. ft 107.3 lbs.

Sample No. 8

Sample No. 8

This sand was obtained from the bank of the Illinois river north of Peoria. It is a fine sand but contains some large particles. This sand is practically free from clay, but contains some vegetable matter, such as is found in sample number 7. Sp. Gr. 2.66 Percent voids 35.1 o/o Wt. per cu. ft. 108.0 lbs.

Summary of Tests.

The results of the tensile tests show that most of the briquettes made of the different sands were fairly strong at twenty-eight days, and this is probably the best age at which to test the strength of a mortar since in practice concrete structures are generally put to use before they acquire the age of ninety days. Starting with sand number one, the briquettes made of this sand were comparatively weak at seven days but their strength increased very rapidly with age. Sands number two and five are not very favorable for mortar making as they showed very little strength at seven days and very little increase with age. The mortar of these two sands showed the least tensile strength with number eight ranking next. Sands number three and four are very similar, showing practically the same tensile strength at seven days, but

three increasing a little more rapidly with age. Sands number six and seven were obtained from the same locality but taken from different deposits. These two sands showed very little difference in mortar making qualities, while the briquettes of number seven were somewhat the stronger at ninety days, those of number six showed an equal amount of tensile strength at seven and twenty eight days. The surprising feature of these tests is, that none of the eight samples tested, ranked as high in tensile strength as the standard Ottowa sand. Number seven ranks one in tensile strength at ninety days, but three which ranks two at ninety days, ranks one at twenty eight days.

In regard to the tensile tests of some of the dirtiest sands, first unwashed and then washed, the results in two cases show that the briquettes made of the unwashed sand possessed greater tensile strength than those made of the

same sand after being washed. In the third case, however, the briquettes of the washed sand were stronger. The fact that only one of the three sands showed an increase in tensile strength after being washed was probably due to the higher percentage of suspended matter, showing that a small amount of clay is not a detriment to the mortar making qualities of a sand while an amount exceeding 3% does decrease the tensile strength.

The sands which showed the least tensile strength, namely: sample numbers two, five, and eight, are very fine and contain practically no coarse material. They also have a comparatively low specific gravity and high percentage of voids. Sand number four showed the highest specific Gravity, the least percentage of voids, but did not rank as high as numbers three and seven in tensile strength. However the five sands showing the best mortar making qualities possess a fairly high specific gravity, differing

very little in this particular, all being fairly well graded and containing considerable coarse material.

Conclusion.

The results of the tests indicate that most of the sands of this state are fairly well adapted for mortar making. In the case of Taylorville, however, it might be more economical for this city to import sand from Hannibal, Mo., or Peoria, than to use the local sand. The sands from either of these places give approximately twice as much tensile strength as the Taylorville sand, with the proportions used in these tests. It is quite likely that the cost of the additional cement necessary with the Taylorville sand in order to attain the same strength as mortar from the other sands, would be greater than the saving affected by using local sand in place of transporting sand for several hundred miles.

The results also indicate that a good mortar making sand should be fairly clean, containing not over $2\frac{1}{2}$ % of clay and no vegetable matter; that it should contain considerable coarse material, be low in percentage of voids and fairly high in specific gravity. The percentage of voids is dependent upon the grading of the particles, the better graded the lower the percentage of voids. Therefore a sand with a small amount of voids, requires less cement and makes a denser mortar, other things being equal. The specific gravity is probably not very important. It indicates to some extent, however, the kind of material constituting the particles. The fineness test is really the best test of the mortar making qualities of a sand. A very fine sand without any coarse material is never suitable for mortar making, since it requires to much cement to coat the

numerous particles besides being difficult to coat them uniformly in mixing the mortar. In conclusion it might be added that Illinois sands in general contain too little coarse grained material.

Description of Tables

Tables 1, 2, 3, and 4, Pages 25 to 29, show the results of the tensile tests.

Table 5, page 29, shows the results of the fineness test.

Table 6, page 30, shows the results of the specific gravity and percentage of voids tests.

Table 7, page 31, shows the ranking of the sands in tensile strength, percentage of voids, and specific gravity. The sands showing the greatest strength, the highest specific gravity, and the least amount of voids were ranked highest in the respespective tests.

Description of Graphs.

Page 32, Curves showing variation of tensile strength with age.

Pages 33 to 40, Seive analysis curves of all the sands.

TABLE No. 1

TENSILE TESTS OF 1:3 MORTAR.

Sample Number	Sand Obtained From	Tesile Strength at 7 Days						Average
—	Neat Cement	620	635	630	640	640	600	628
—	Ottawa	180	175	175	170	175	180	176
1	Paris	105	110	100	110	100	95	103
2	Taylorville	80	75	75	85	95	100	85
3	Cairo	130	130	120	130	150	120	130
4	Jacksonville	130	125	125	145	145	150	137
5	Mt. Carmel	90	90	80	90	95	95	90
6	Peoria	175	150	160	165	150	150	158
7	Peoria	140	120	150	160	130	160	143
8	Peoria	120	110	110	105	115	125	114

TABLE No. 2

TENSILE TESTS OF 1:3 MORTAR.

Sample Number	Sand Obtained From	Tensile Strength at 28 Days						Average
—	Neat Cement	745	735	725	710	690	715	720
—	Ottawa	260	230	245	245	230	250	243
1	Paris	175	190	150	170	160	160	168
2	Taylorville	90	120	100	115	100	120	108
3	Cairo	190	190	195	185	230	200	198
4	Jacksonville	180	160	185	150	180	—	171
5	Mt. Carmel	120	140	130	115	130	110	124
6	Peoria	180	180	175	185	195	190	184
7	Peoria	195	185	185	170	200	200	189
8	Peoria	155	155	145	145	160	160	153

TABLE No. 3

TENSILE TESTS OF 1:3 MORTAR.

Sample Number	Sand Obtained From	Tensile Strength at 90 Days						Average
—	Neat Cement	810	815	810	840	825	800	816
—	Ottawa	310	315	310	315	310	315	312
1	Paris	220	205	220	205	240	215	218
2	Taylorville	155	160	140	160	175	160	158
3	Cairo	255	250	255	275	230	240	251
4	Jacksonville	240	220	240	225	225	225	229
5	Mt. Carmel	170	160	160	150	145	145	155
6	Peoria	210	235	240	235	250	245	236
7	Peoria	275	270	255	245	275	260	263
8	Peoria	185	170	190	180	165	180	178

TABLE No. 4

TENSILE TESTS OF 1:3 MORTAR.

Sample Number	Sand Obtained From.	Tensile Strength.						Average.
		Sands Unwashed.						
2	Taylorville	150	150	140	140	150	150	147
5	Mt. Carmel	150	135	150	145	130	150	143
7	Peoria	210	220	250	220	220	210	223
		Sands Washed.						
2	Taylorville	140	155	155	150	160	160	153
5	Mt. Carmel	140	120	120	120	140	120	127
7	Peoria	180	190	200	210	205	205	198

TABLE No. 5

FINENESS TEST

Sample Number	Obtained From	% Suspended Matter	Percents Passing Seives No. 200	150	100	74	60	40	30	20	16	10	8	5	0.2"
1	Paris	1.20	1.53	2.55	3.47	12.40	16.37	64.35	91.15	97.41	97.97	99.06	99.37	99.82	100
2	Taylorville	3.94	7.33	9.34	22.06	55.56	75.35	99.55	99.84	99.91	99.93	99.97	100	100	100
3	Cairo	0.26	0.29	0.35	0.63	2.33	3.76	24.85	61.91	80.92	83.77	94.65	97.10	98.79	100
4	Jacksonville	0.25	0.34	0.49	1.10	3.64	7.15	33.04	58.47	76.89	80.38	93.32	96.12	99.31	100
5	Mt. Carmel	2.34	2.57	2.68	3.91	18.82	34.23	98.82	99.83	99.90	99.94	99.97	100	100	100
6	Peoria	2.70	3.14	3.53	6.05	14.56	17.90	47.97	75.13	88.40	90.34	96.74	98.01	99.51	100
7	Peoria	1.85	2.28	2.35	2.50	2.93	3.90	19.96	59.54	83.74	86.65	96.38	98.08	99.38	100
8	Peoria	0.56	0.66	0.72	1.77	9.07	13.10	68.30	88.66	95.36	97.14	99.02	99.38	99.72	100

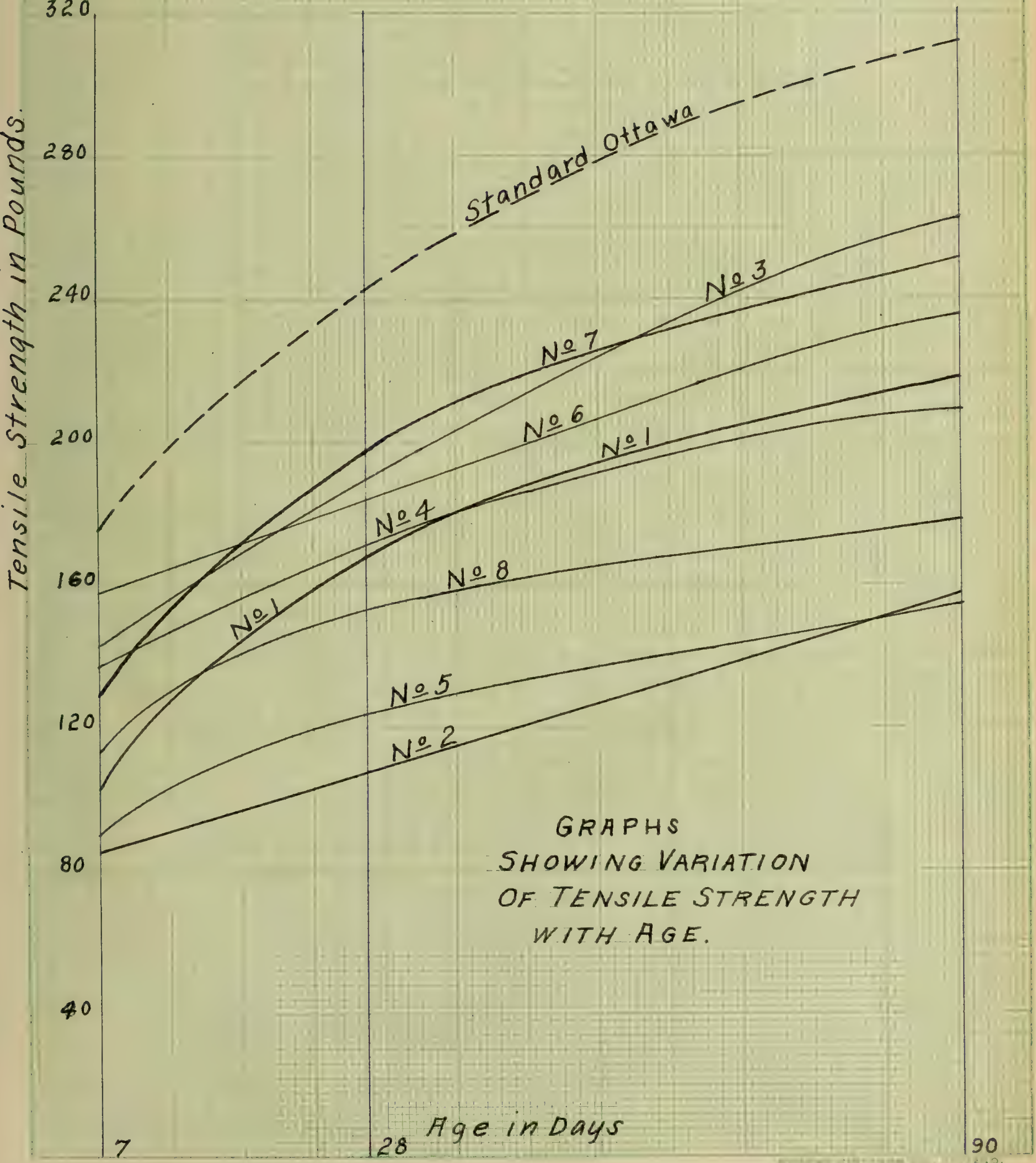
TABLE No. 6.

SPECIFIC GRAVITY TESTS									
Sample No.	1	2	3	4	5	6	7	8	Ottawa
No. G'ms Sand Used	50	50	50	50	50	50	50	50	50
Vol. (c. cms.) water displaced by sand.	18.95	19.05	18.95	18.55	19.20	18.95	18.85	18.90	19.10
	18.85	18.85	18.90	18.55	19.10	18.70	18.95	18.60	18.90
Average	18.90	18.95	18.93	18.55	19.15	18.83	18.90	18.75	19.00
Specific Gravity	2.65	2.64	2.64	2.69	2.61	2.66	2.65	2.66	2.63
PERCENT OF VOIDS TESTS									
Weight (G'ms) 500 c.cms. sand	848.5	796.8	861.9	913.3	811.1	880.8	860.8	862.9	864.6
	852.8	798.8	860.1	916.0	809.9	880.4	859.6	862.5	865.4
	852.5	797.8	857.3	916.8	808.7	879.2	859.2	862.4	866.3
Average	851.3	797.5	859.8	915.4	809.9	880.1	859.9	862.6	865.4
Percent of Voids	35.8	39.5	35.0	31.9	38.1	33.8	35.0	35.1	34.2

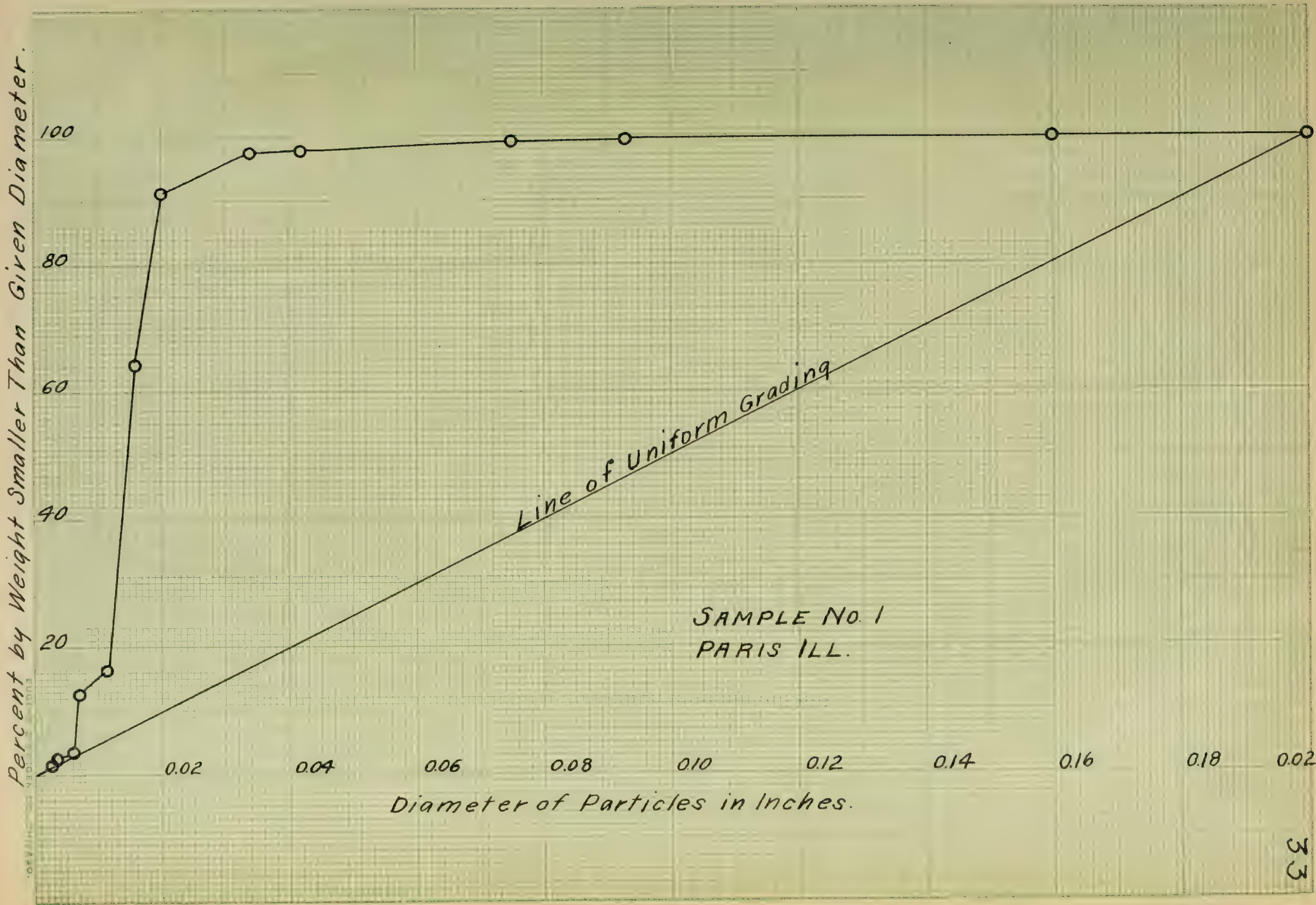
TABLE No. 7.

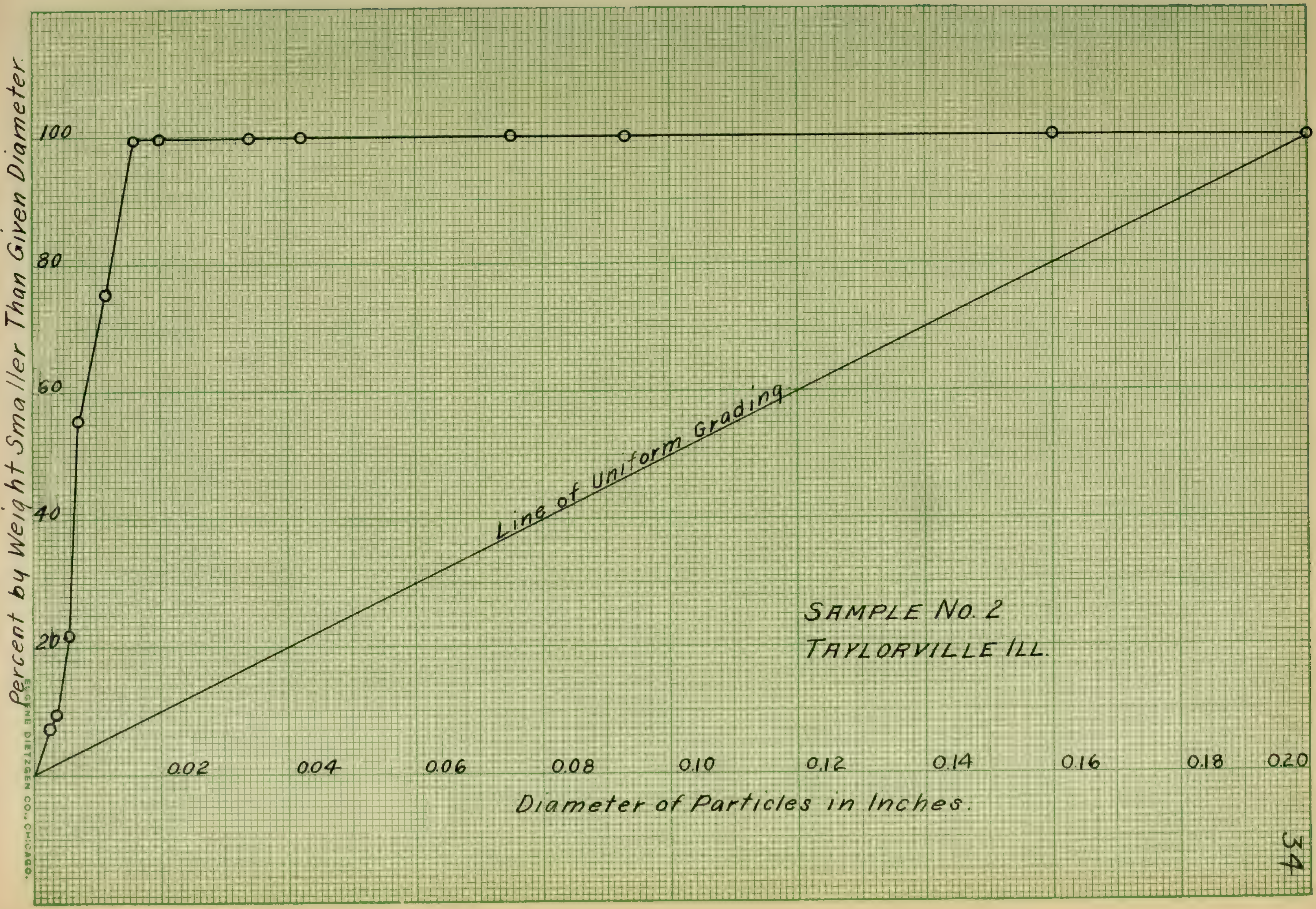
RANKING OF SANDS.

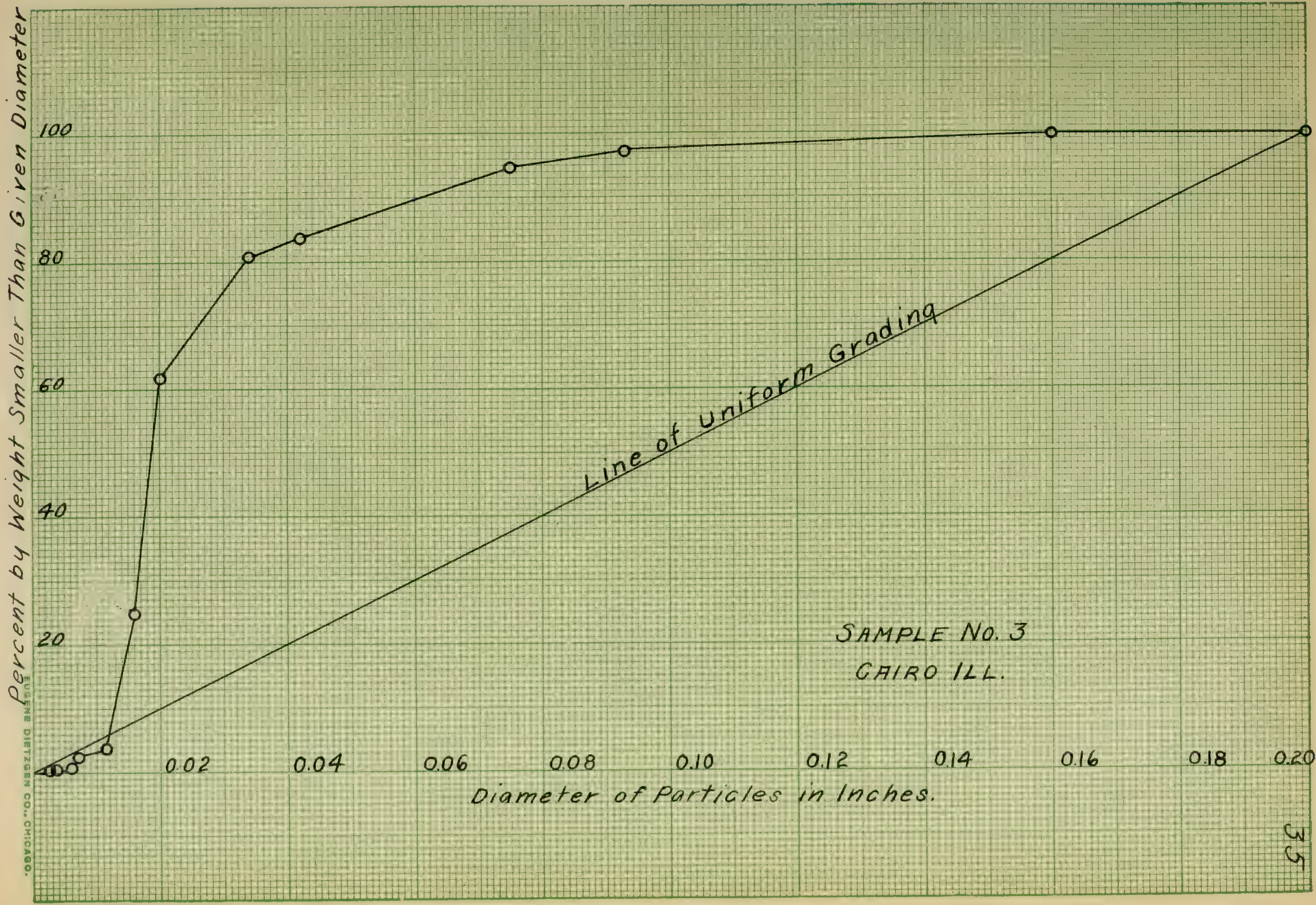
Sample Number	Sand Obtained From.	Tensile Strength	Percentage of Voids.	Specific Gravity.
3	Cairo	1	3	6
7	Peoria	2	3	4
6	Peoria	3	2	2
4	Jacksonville	4	1	1
1	Paris	5	6	4
8	Peoria	6	5	2
5	Mt. Carmel	7	7	8
2	Taylorville	8	8	6

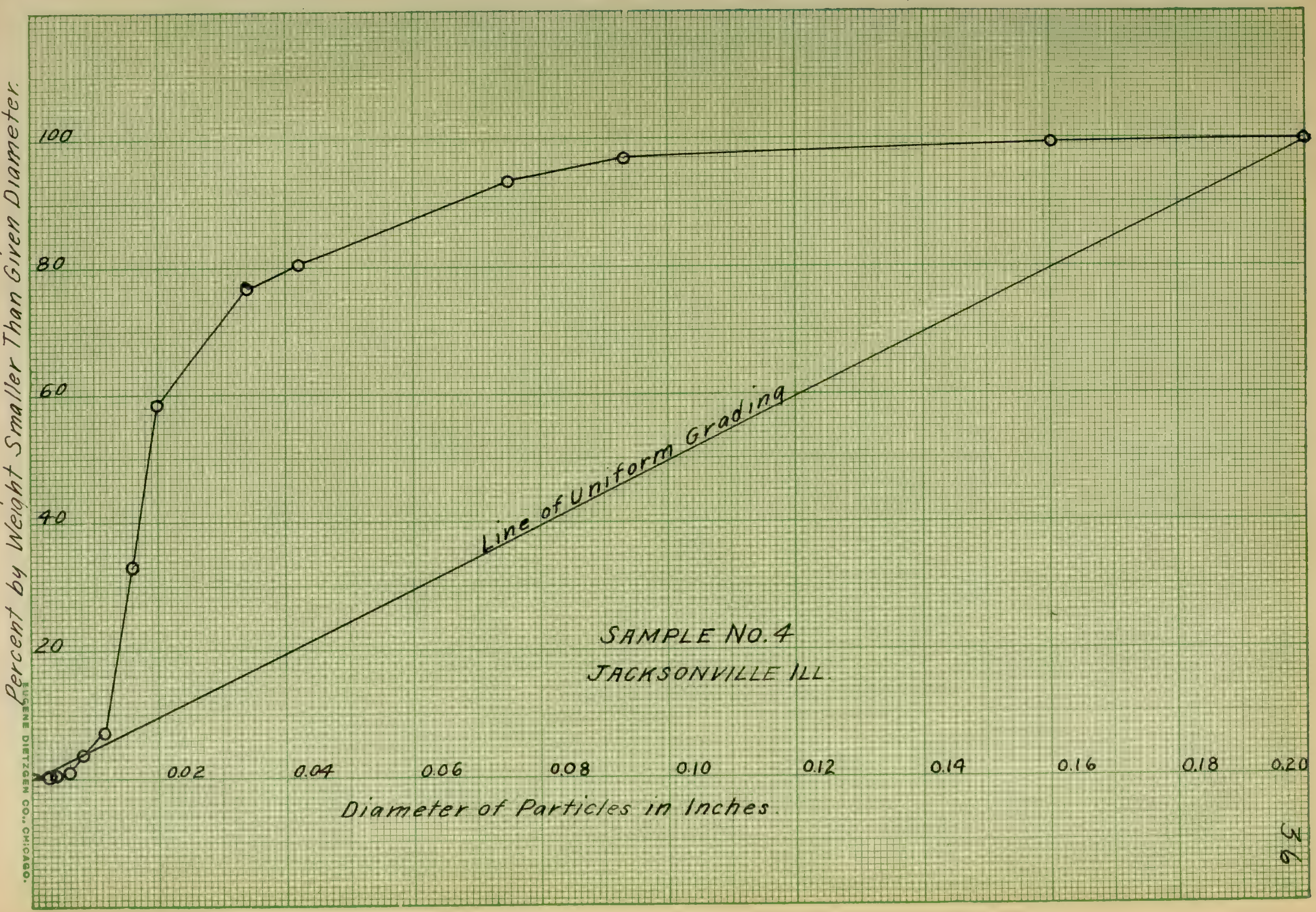


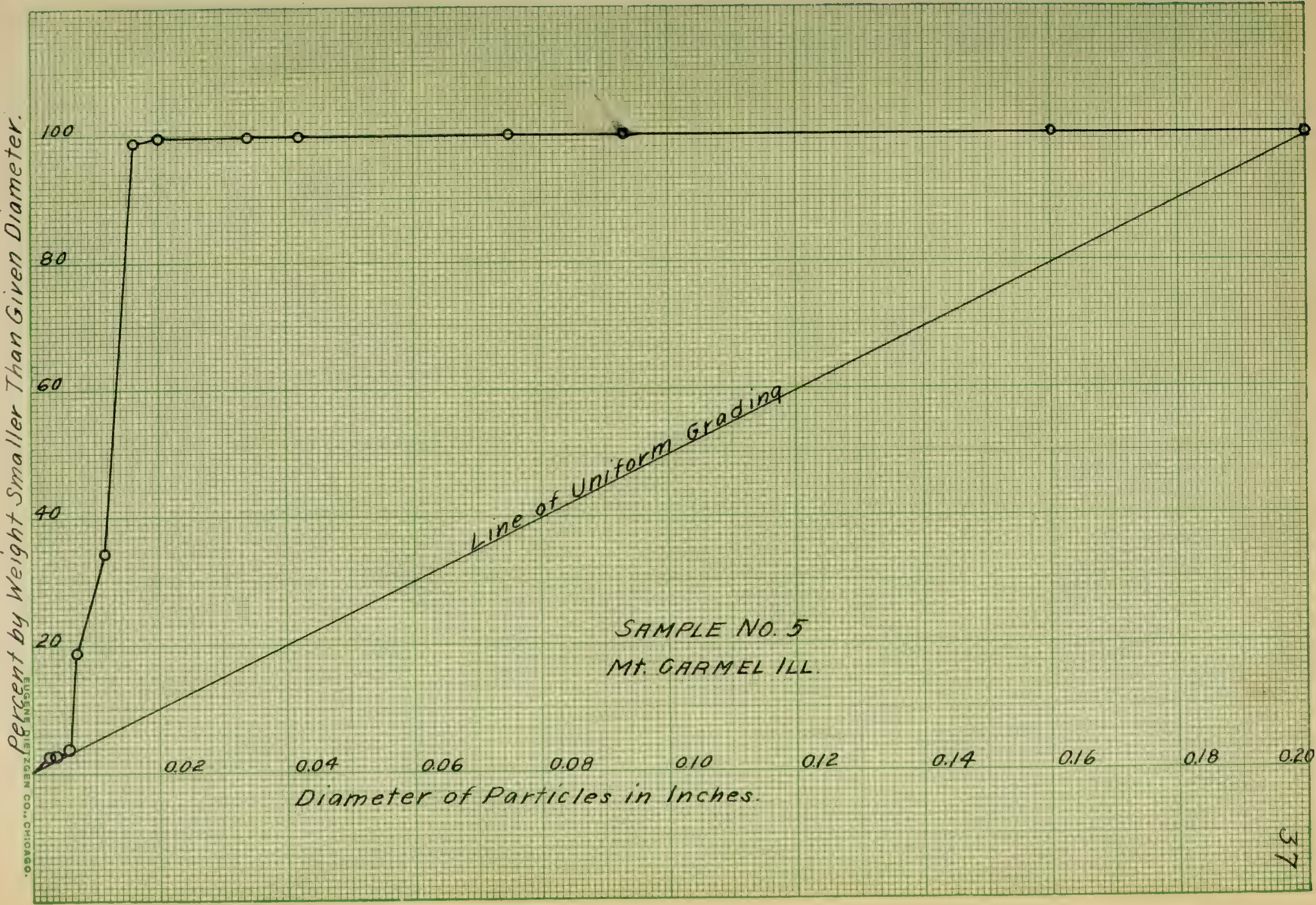
Tensile Strength in Pounds.
320
280
240
200
160
120
80
40
Standard Ottawa
Nº 3
Nº 7
Nº 6
Nº 1
Nº 4
Nº 8
Nº 1
Nº 5
Nº 2
GRAPHS
SHOWING VARIATION
OF TENSILE STRENGTH
WITH AGE.
Age in Days
7
28
90

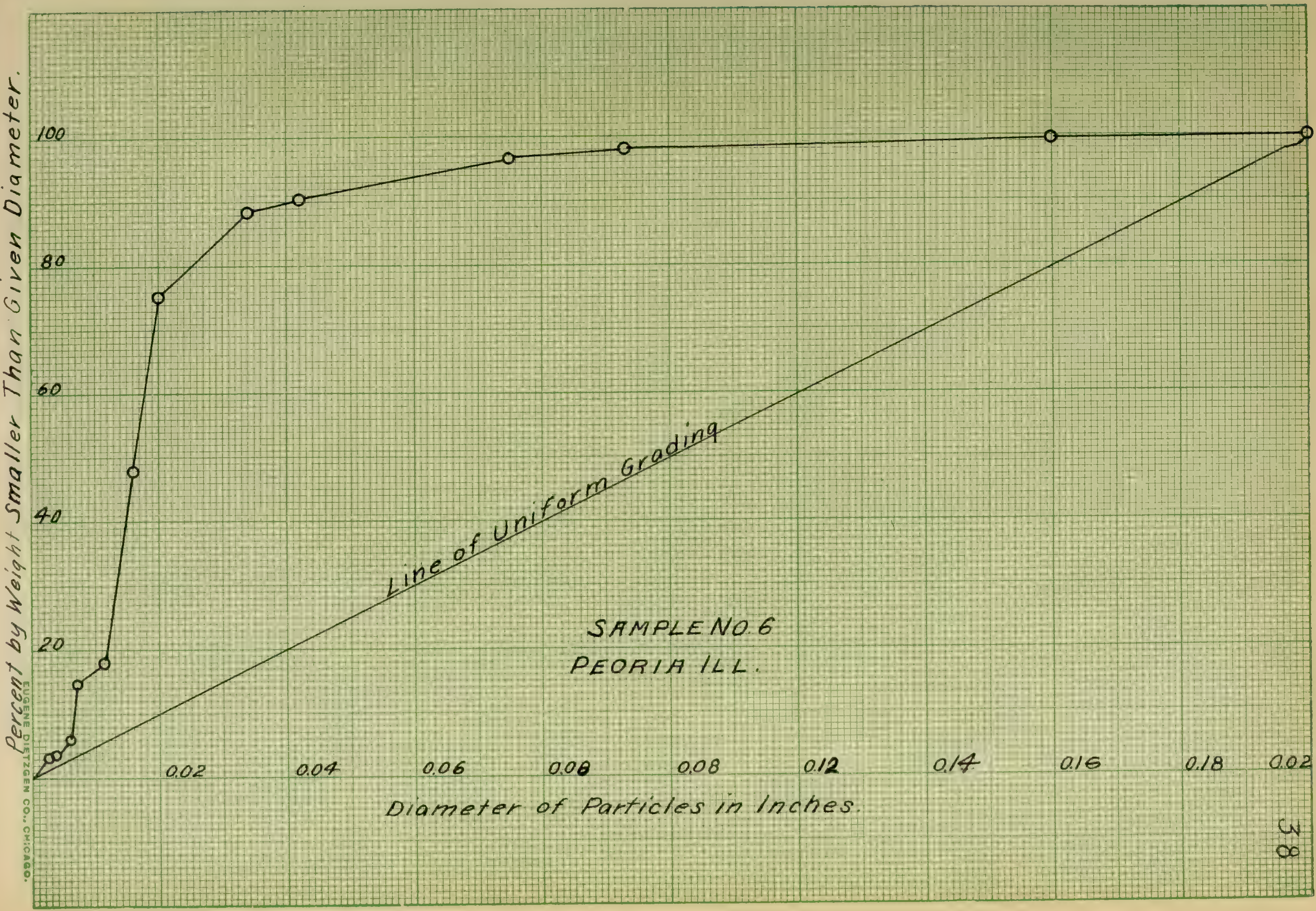

Percent by Weight Smaller Than Given Diameter.
100
80
60
40
20
0.02
0.04
0.06
0.08
0.10
0.12
0.14
0.16
0.18
0.02
Diameter of Particles in Inches.
Line of Uniform Grading
SAMPLE No. 1
PARIS ILL.

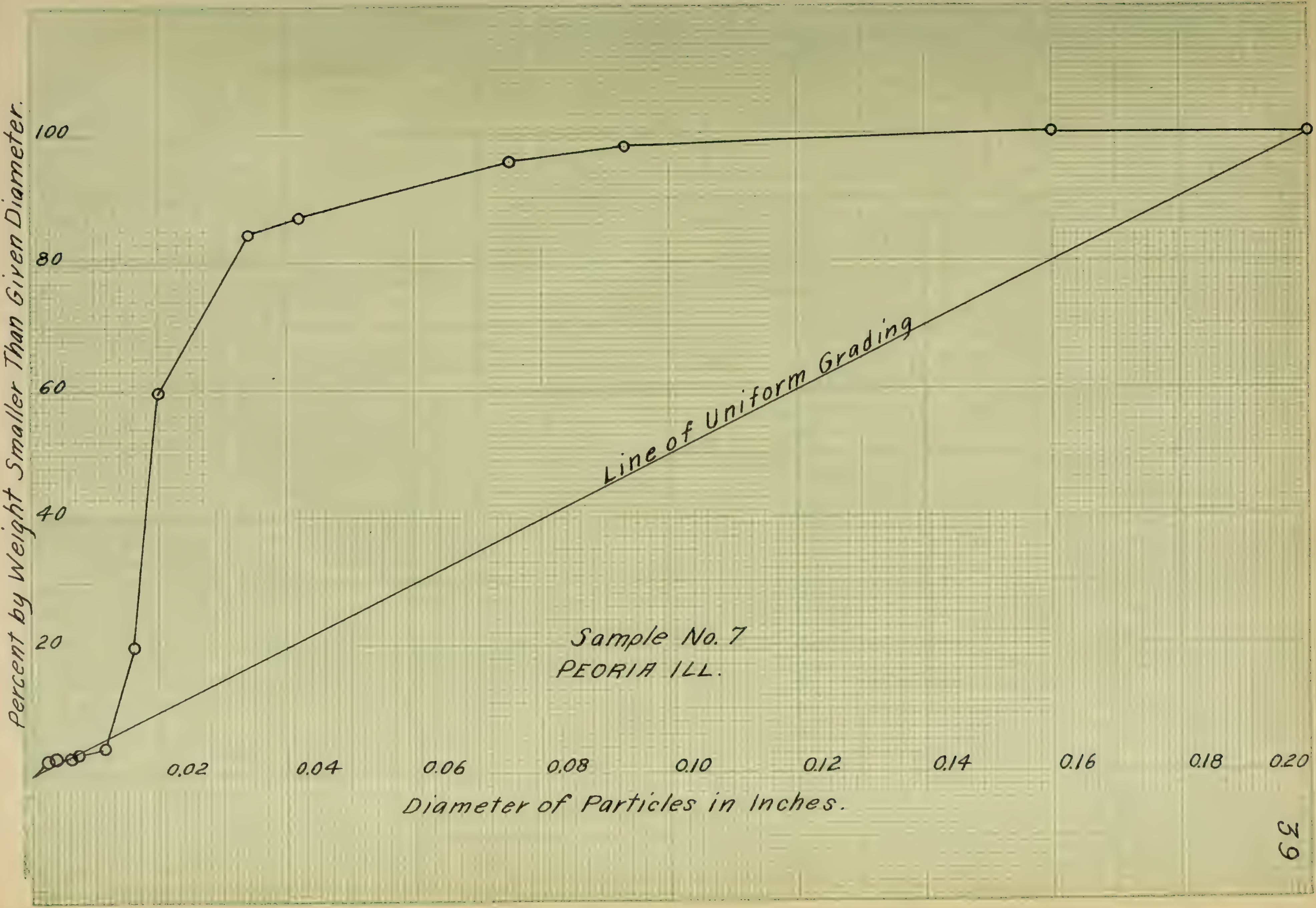

Percent by Weight Smaller Than Given Diameter.
100
80
60
40
20
0.02
0.04
0.06
0.08
0.10
0.12
0.14
0.16
0.18
0.20
Diameter of Particles in Inches.
Line of Uniform Grading
SAMPLE No. 2
TAYLORVILLE ILL.
34
EUGENE DIETZGEN CO., CHICAGO.

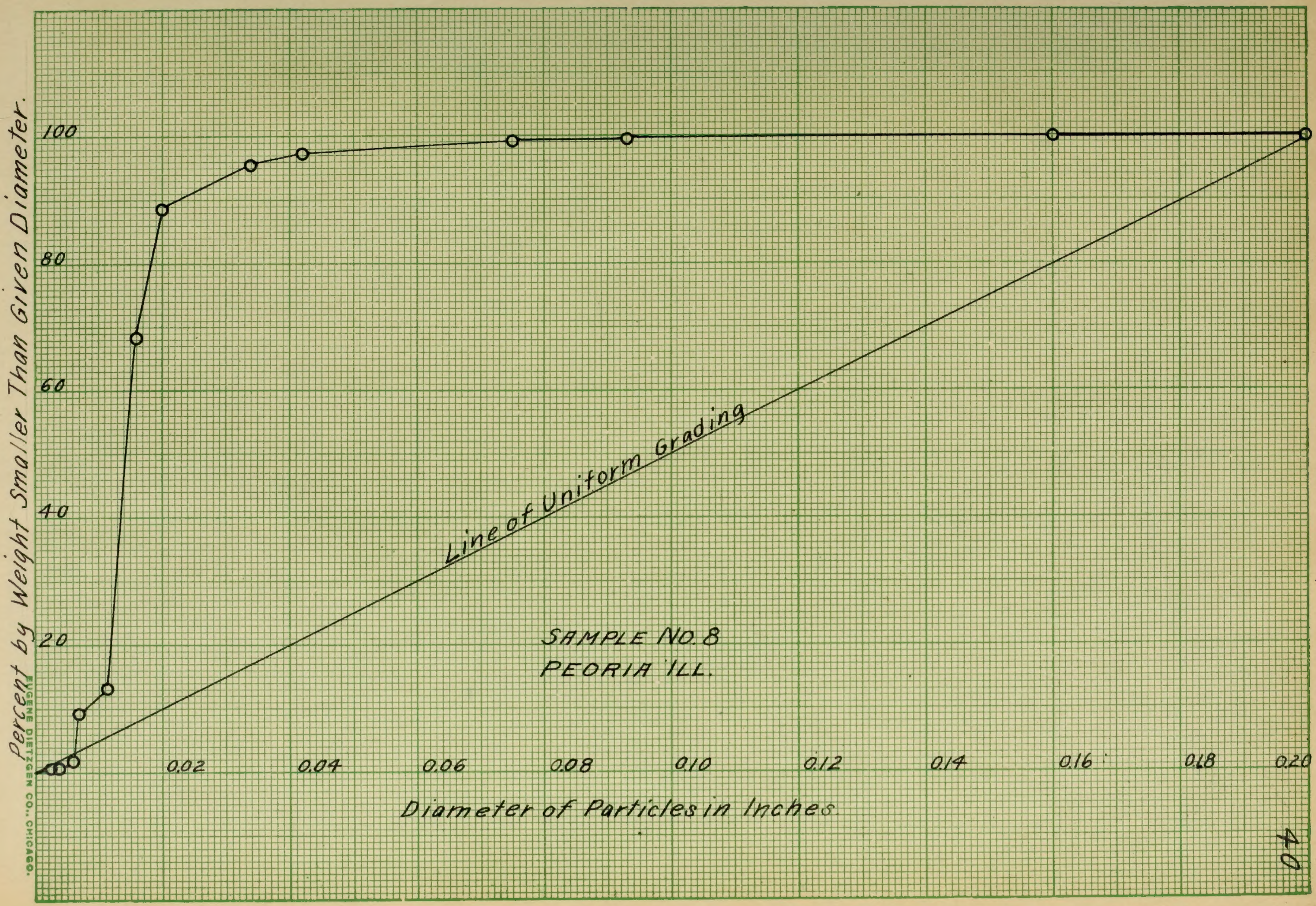

Percent by Weight Smaller Than Given Diameter
100
80
60
40
20
0.02
0.04
0.06
0.08
0.10
0.12
0.14
0.16
0.18
0.20
Diameter of Particles in Inches.
Line of Uniform Grading
SAMPLE No. 3
CAIRO ILL.
EUGENE DIETZGEN CO., CHICAGO.


36
Percent by Weight Smaller Than Given Diameter.
100
80
60
40
20
0.02
0.04
0.06
0.08
0.10
0.12
0.14
0.16
0.18
0.20
Diameter of Particles in Inches.
Line of Uniform Grading
SAMPLE NO. 4
JACKSONVILLE ILL.
EUGENE DIETZGEN CO., CHICAGO.


Percent by Weight Smaller Than Given Diameter.
100
80
60
40
20
0.02
0.04
0.06
0.08
0.10
0.12
0.14
0.16
0.18
0.20
Diameter of Particles in Inches.
Line of Uniform Grading
SAMPLE NO. 5
Mt. CARMEL ILL.
EUGENE DIETZGEN CO., CHICAGO.


Percent by Weight Smaller Than Given Diameter.
100
80
60
40
20
Line of Uniform Grading
SAMPLE NO. 6
PEORIA ILL.
0.02
0.04
0.06
0.08
0.08
0.12
0.14
0.16
0.18
0.02
Diameter of Particles in Inches.
38
EUGENE DIETZGEN CO., CHICAGO.


Percent by Weight Smaller Than Given Diameter.
100
80
60
40
20
0.02
0.04
0.06
0.08
0.10
0.12
0.14
0.16
0.18
0.20
Diameter of Particles in Inches.
Line of Uniform Grading
Sample No. 7
PEORIA ILL.


Percent by Weight Smaller Than Given Diameter.
100
80
60
40
20
0.02
0.04
0.06
0.08
0.10
0.12
0.14
0.16
0.18
0.20
Diameter of Particles in Inches.
Line of Uniform Grading
SAMPLE NO. 8
PEORIA ILL.
EUGENE DIETZGEN CO., CHICAGO.